PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re application of	Docket No: Q77958
Eric MONTFORT, et al.	
Appln. No.: 10/687,585	Group Art Unit: 3664
Confirmation No.: 2460	Examiner: Brian J. BROADHEAD
Filed: October 20, 2003	

For: A SYSTEM FOR CONTROLLING THE ATTITUDE OF A GEOSTATIONARY SATELLITE

REPLY BRIEF PURSUANT TO 37 C.F.R. § 41.41

MAIL STOP APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with the provisions of 37 C.F.R. § 41.41, Appellant respectfully submits this Reply Brief in response to the Examiner's Answer dated March 17, 2008. Entry of this Reply Brief is respectfully requested.

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STATUS OF CLAIMS

Claims 4-16 are pending in the application and are the subject of this appeal.

Claims 1-3 have been previously canceled without prejudice or disclaimer, and are not the subject of this appeal.

GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Ground 1

Claims 15 and 16 are rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement.

Ground 2

Claims 8, 10, 12 and 13 remain rejected under 35 U.S.C. § 102(b) as being anticipated by Heiberg (U.S. Patent No. 5,944,761).

Ground 3

Claims 4, 6 and 14-16 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Heiberg.

Ground 4

Claims 5, 7, 9 and 11 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Heiberg in view of Parvez et al. (U.S. Patent No. 6,089,507).

ARGUMENT

In this Reply Brief, Appellants address below certain points raised in the Examiner's Answer as mailed on March 17, 2008.

Ground 1

In maintaining the rejection of claims 15 and 16 under 35 U.S.C. § 112, first paragraph, the Examiner alleges that "from a drawing it is impossible to tell if the elongate[d] members are [of] a fixed length. . . . [and that drawings] cannot easily show movement since they are only a representation of a single point in time." *See* Answer at pages 6-7. Applicants respectfully disagree with the Examiner's position. For example, FIG. 2 shows a wheel 22 that rotates around its axis 24. The movement is shown by the arrow depicted on the surface of the wheel which clearly indicates that the wheel rotates counterclockwise.

It goes without saying that arrows can also be used to depict translational movement, as it may be the case, for example, with solar generators. Other means of showing movement in drawings are, for example, dashed lines, multiple views depicting different stages and three-dimensional views.

Neither arrows nor dashed lines or any other method for showing a movement are used in FIG. 1 that would imply that the solar generators vary in length once unfolded. As a consequence, one of ordinary skill in the art would interpret FIG. 1 to support having the length of the solar generators fixed as there is no translational movement of parts depicted. Therefore, there is § 112, first paragraph support on claims 15 and 16.

Ground 2

As Heiberg is mainly concerned with vibrations from disturbances which have frequency contents that vary with time, Heiberg does not disclose or suggest an attitude regulation loop that "contains the lowest and most energetic frequencies of the flexible modes," as recited in claim 8. Specifically, Heiberg discloses the frequency rejection system 10 in FIG. 1 as an example for compensation disturbances of a fixed frequency in order to distinguish his control system from the prior art. With respect to such a fixed frequency rejection system, Heiberg does not even address the issue of operating such a system in different frequency bands. It is known in the art that disturbances of different sources result in vibrations that differ in vibration frequency and vibration energy. It is also known in the art, that a compensator, as described in Heiberg, is not capable of compensating all possible frequencies that may occur as a result of any possible disturbance. Rather, such systems operate in a certain frequency band with a certain bandwidth.

In maintaining the rejection of claims 8, 10, 12 and 13 under 35 U.S.C. § 102(b) as being anticipated by Heiberg, the Examiner discusses his understanding of how disturbances can occur and at what frequencies oscillations are caused. The Examiner discusses disturbances disclosed in Heiberg that result from "temperature differences [that] can suddenly cause parts of the spacecraft to snap or sharply bend and, in so doing, produce vibrations." *See* col. 1, lines 15-20. The Examiner then continues his argument with an example of a PVC pipe held at the center and that is moved up and down. The Examiner notes that for different lengths of the pipe, the ends if the pipe shake at different rates and that the frequency of the vibration of the ends of the pipe is a function of the length of the pipe and of its material. While this may generally be true, it has no

bearing on whether Heiberg teaches a loop that contains the lowest and most energetic frequencies of flexible modes of the elongated members, as recited in claim 8.

The Examiner, however, seems to acknowledge these facts when he states that "[t]he bandwidth of the corrector is where in the frequency spectrum the controller will look for disturbances to correct [and if] the bandwidth doesn't include the frequency at which the solar generators are moving [because of the particular disturbance], then the controller would not activate the CMGs." *See* Answer at page 8. In other words, the controller, described by the Examiner, does not necessarily cover the whole possible bandwidth of all possible disturbance frequencies.

However, Applicants respectfully disagree with the Examiner's conclusion that "Heiberg requires the 'lowest and most energetic frequencies of the flexible modes of the elongated members' be included in their corrector [because] otherwise the invention would simply not work and perform its intended function." *See* Answer at page 10.

For compensating disturbances, two different approaches are known, namely feedback and feedforward control. The Examiner may review literature on this subject, for example, pages 5-9 of André Preumont, *Vibration Control of Active Structures An Introduction* (Kluwer Academic Publishers) (2d ed. 2002)[1] (hereinafter "Preumont"). In FIG. 1 and col. 2, lines 15-67,

[1] The book is available online at http://books.google.com/books?id=FnIJEb5gzK0C&printsec=copyright&dq=Vibration+Control+of+Active+Structures&source=gbs_toc_s&cad=1#PPP1,M1. Applicants have attached screen shots of the cover page and pages 5 and 7-9.

Heiberg discloses a fixed frequency rejection system that clearly follows the principle of feedback control. Such a system is also depicted at page 8 of Preumont.

It is well known in the art that "[t]he bandwidth ω_c of the control system is limited by the accuracy of the model; there is always some destabilization of the flexible modes outside ω_c." *See* Preumont at page 9. Furthermore, it is also well known in the art that "[o]ne should always bear in mind that feedback control can compensate for external disturbance only in a limited frequency band that is called the bandwidth of the control system. One should never forget that outside the bandwidth, the disturbance is actually amplified by the control system." *See* Preumont at page 5. In other words, the bandwidth of a feedback control system does not necessarily cover the complete frequency spectrum in which disturbances can occur. The bandwidth clearly depends from the accuracy and kind of the model that is used to implement the controller.

Heiberg does not disclose or suggest that the model of the compensator is designed to cover the complete bandwidth of all possible frequencies that can result from all possible disturbances. By contrast, the fixed frequency rejection system in Heiberg is only related to disturbances originated by thermal variances and the like. Disturbances caused by sloshing of fuel of the propulsion system are completely different and require a different accuracy of the model of the controller.

Therefore, one cannot conclude that "lowest and more energetic frequencies" that result from sloshing of fuel instead of from thermal variances are automatically covered by the bandwidth of a feedback control system, as disclosed, for example, in Heiberg. By contrast,

according to the above-discussion, since Heiberg does not explicitly teach that its compensator also covers "lowest and more energetic frequencies", an attempt of Heiberg's system to compensate such disturbances could even result in an amplification of such disturbances.

As a result, Applicant submits that Heiberg does not require that the "lowest and most energetic frequencies of the flexible modes of the elongated members" be included, as recited in claim 8. Instead, to function properly in its bandwidth (that depends from the accuracy of the model of the compensator), Heiberg needs only to make sure that the compensator only recognizes frequencies in its bandwidth, leaving out frequencies that are outside the frequency bandwidth of the compensator to avoid amplifying these disturbances.

With respect to the second embodiment of Heiberg, the Examiner states that "the smaller peaks in the graph of 116 are never described and it is not clear where they would come from. For all we know, these small peaks are measurement errors." *See* Answer at page 9. The Examiner's interpretation of graph 116 is incorrect. This graph does not contain errors. Instead, it shows a frequency spectrum that is generated from a rate signal. *See* col. 3, lines 21-24 of Heiberg. As discussed above, disturbances do not result in oscillations of only one frequency. Instead, since systems may have different resonance frequencies, such disturbances always result in a plurality of frequencies. While graph 116 shows the complete frequency spectrum of an exemplary disturbance, the filter narrows down its bandwidth so that only the frequency with the main peak is compensated.

For at least the reasons stated here and in Appellant's Appeal Brief, the Examiner's rejection of claims 8, 10, 12 and 13 under 35 U.S.C. § 102(b) is improper and should be reversed.

Grounds 3 and 4

Regarding grounds 3 and 4, the Examiner did not raise new issues. Instead, the rejection of claims 4-7, 9, 11 and 14-16 is based on the same flawed analysis of Heiberg, as applied by the Examiner to claims 8, 10, 12 and 13.

CONCLUSION

For the above reasons as well as the reasons set forth in Appeal Brief, Appellant respectfully requests that the Board reverse the Examiner's rejections of all claims on Appeal. An early and favorable decision on the merits of this Appeal is respectfully requested.

Respectfully submitted,

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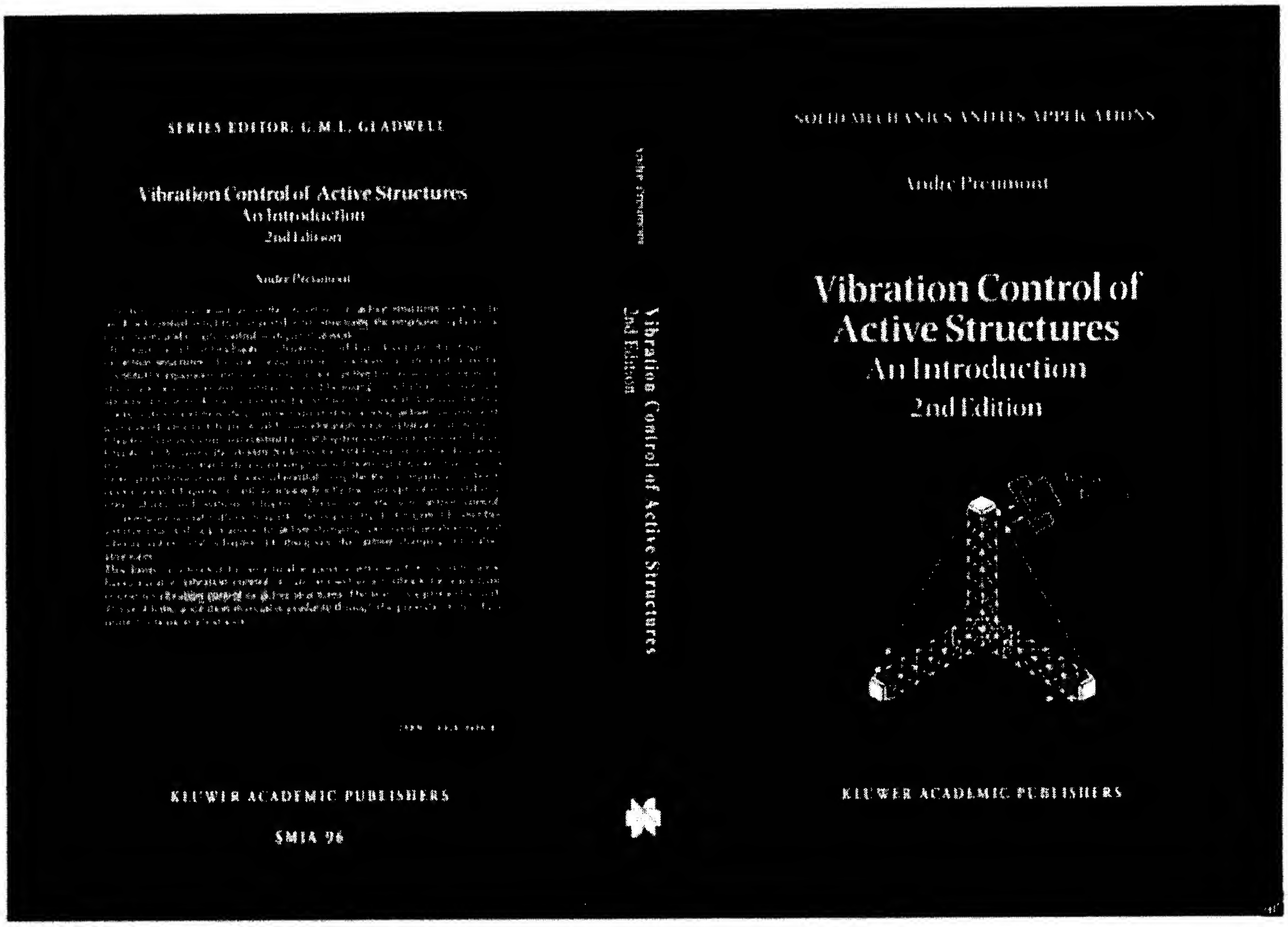

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control module and the supporting truss; this isolator allows the low frequency attitude control torque to be transmitted, while filtering out the high frequency disturbances generated by the unbalanced centrifugal forces in the reaction wheels. The same general purpose vibration isolator may be used at the interface between the truss and the independent telescopes; in this case however, its vibration isolation capability is combined with the steering (pointing) of the telescopes. The third component relevant to active control is the optical delay line; it consists of a high precision single degree of freedom translational mechanism supporting a mirror, whose function is to control the path length between every telescope and the beam combiner, so that these distances are kept identical to a fraction of the wavelength (e.g. $\lambda/20$).

These examples were concerned mainly with performance. However, as technology develops and with the availability of low cost electronic components, it is likely that there will be a growing number of applications where active solutions will become cheaper than passive ones, for the same level of performance.

The reader should not conclude that *active* will always be better and that a control system can compensate for a bad design. In most cases, a bad design will remain bad, active or not, and an active solution should normally be considered only after all other passive means have been exhausted. One should always bear in mind that feedback control can compensate for external disturbances only in a limited frequency band that is called the *bandwidth* of the control system. One should never forget that outside the bandwidth, the disturbance is actually amplified by the control system.

In recent years, there has been a growing interest in *semi-active* control, particularly for vehicle suspensions; this has been driven by the reduced cost as compared to active control, due mainly to the absence of a large power actuator. A semi-active device can be broadly defined as a passive device in which the properties (stiffness, damping, ...) can be varied in real time with a low power input. Although they behave in a strongly nonlinear way, semi-active devices are inherently passive and, unlike active devices, cannot destabilize the system; they are also less vulnerable to power failure. Semi-active suspension devices may be based on classical viscous dampers with a variable orifice, or on magneto-rheological (*MR*) fluids.

1.2 Smart materials and structures

An active structure consists of a structure provided with a set of actuators and sensors coupled by a controller; if the bandwidth of the controller includes some vibration modes of the structure, its dynamic response must be considered. If the set of actuators and sensors are located at discrete points of the structure, they can be treated separately. The distinctive feature of *smart* structures is that the actuators and sensors are often distributed, and have a high degree of integration inside the structure, which makes a separate modelling impossible

- *Magnetostrictive materials* have a recoverable strain of 0.15 % under magnetic field; the maximum response is obtained when the material is subjected to compressive loads. Magnetostrictive actuators can be used as load carrying elements (in compression alone) and they have a long lifetime. They can also be used in high precision applications. The best known is the *TERFENOL-D*.
- *Magneto-rheological* (*MR*) fluids consists of viscous fluids containing micron-sized particles of magnetic material. When the fluid is subjected to a magnetic field, the particles create columnar structures requiring a minimum shear stress to initiate the flow. This effect is reversible and very fast (response time of the order of millisecond). Some fluids exhibit the same behaviour under electrical field; they are called *electro-rheological* (*ER*) fluids; however, their performances (limited by the electric field breakdown) are significantly inferior to *MR* fluids. *MR* and *ER* fluids are used in semi-active devices.

This brief list of commercially available smart materials is just a flavor of what is to come: ***phase change materials*** are currently under development and are likely to become available in a few years time; they will offer a recoverable strain of the order of 1 % under an electric field, one order of magnitude more than the piezoceramics.

The range of available devices to measure position, velocity, acceleration and strain is extremely wide, and there are more to come, particularly in optomechanics. Displacements can be measured with inductive, capacitive and optical means (laser interferometer); the latter two have a resolution in the nanometer range. Piezoelectric accelerometers are very popular but they cannot measure a d.c. component. Strain can be measured with strain gages, piezoceramics, piezopolymers and fiber optics. The latter can be embedded in a structure and give a global average measure of the deformation; they offer a great potential for health monitoring as well. We will see that piezopolymers can be shaped to react only to a limited set of vibration modes (modal filters).

1.3 Control strategies

There are two radically different approaches to disturbance rejection: feedback and feedforward. Although this text is entirely devoted to feedback control, it is important to point out the salient features of both approaches, in order to enable the user to select the most appropriate one for a given application.

1.3.1 Feedback

The principle of feedback is represented in Fig.1.4; the output y of the system is compared to the reference input r, and the error signal, $e = r - y$, is passed

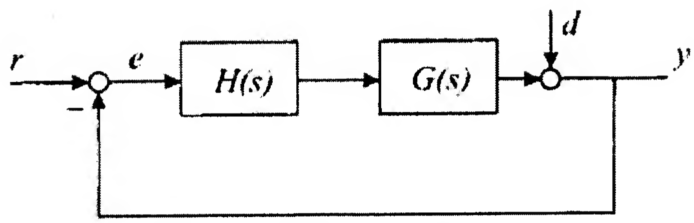

Figure 1.4: *Principle of feedback control*

into a compensator $H(s)$ and applied to the system $G(s)$. The design problem consists of finding the appropriate compensator $H(s)$ such that the closed-loop system is stable and behaves in the appropriate manner.

In the control of lightly damped structures, feedback control is used for two distinct and somewhat complementary purposes: *active damping* and *model based* feedback.

The objective of active damping is to reduce the effect of the resonant peaks on the response of the structure. From

$$\frac{y(s)}{d(s)} = \frac{1}{1+GH} \tag{1.3}$$

(Problem P.1.2), this requires $GH \gg 1$ near the resonances. Active damping can generally be achieved with moderate gains: another nice property is that it can be achieved without a model of the structure, and with guaranteed stability, provided that the actuator and sensor are collocated and have perfect dynamics. Of course actuators and sensors always have finite dynamics and any active damping system has a finite bandwidth.

The control objectives can be more ambitious, and we may wish to keep a control variable y (a position, or the pointing of an antenna) to a desired value r in spite of external disturbances d in some frequency range. From the previous formula and

$$F(s) = \frac{y(s)}{r(s)} = \frac{GH}{1+GH} \tag{1.4}$$

we readily see that this requires large values of GH in the frequency range where $y \simeq r$ is sought. $GH \gg 1$ implies that the closed-loop transfer function $F(s)$ is close to 1, which means that the output y tracks the input r accurately. From Equ.(1.3), this also ensures disturbance rejection within the bandwidth of the control system. In general, to achieve this, we need a more elaborate strategy involving a mathematical model of the system which, at best, can only be a low-dimensional approximation of the actual system $G(s)$. There are many techniques available to find the appropriate compensator, and only the simplest and the best established will be reviewed in this text. They all have a number of common features:

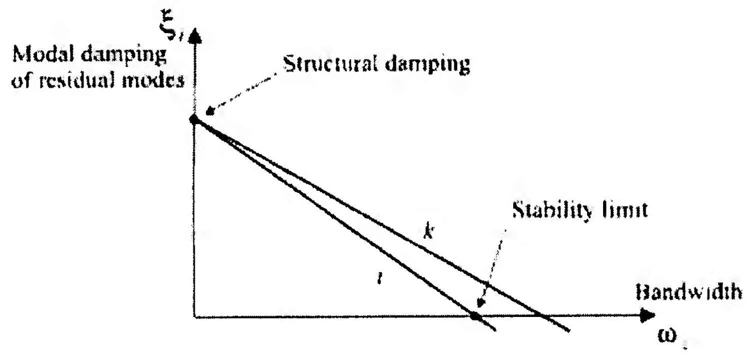

Figure 1.5: *Effect of the control bandwidth on the net damping of the residual modes.*

- The bandwidth ω_c of the control system is limited by the accuracy of the model; there is always some destabilization of the flexible modes outside ω_c (residual modes). The phenomenon whereby the net damping of the residual modes actually decreases when the bandwidth increases is known as *spillover* (Fig.1.5).
- The disturbance rejection within the bandwidth of the control system is always compensated by an amplification of the disturbances outside the bandwidth.
- When implemented digitally, the sampling frequency ω_s must always be two orders of magnitude larger than ω_c to preserve reasonably the behaviour of the continuous system. This puts some hardware restrictions on the bandwidth of the control system.

1.3.2 Feedforward

When a signal correlated to the disturbance is available, feedforward adaptive filtering constitutes an attractive alternative to feedback for disturbance rejection; it was originally developed for noise control (Nelson & Elliott), but it is very efficient for vibration control too (Fuller et al.). Its principle is explained in Fig.1.6. The method relies on the availability of a reference signal correlated to the primary disturbance; this signal is passed through an adaptive filter, the output of which is applied to the system by secondary sources. The filter coefficients are adapted in such a way that the error signal at one or several critical points is minimized. The idea is to produce a secondary disturbance such that it cancels the effect of the primary disturbance at the location of the error sensor. Of course, there is no guarantee that the global response is also reduced at